Arizona Department of Transportation
Bridge Group

BRIDGE PRACTICE GUIDELINES

SECTION 10- FOUNDATIONS AND SUBSTRUCTURES

Chapter	Page	Issue Date
SCOPE	3	7/2/01
DEFINITIONS	3	7/2/01
FOUNDATION	4	7/2/01
Drilled Shaft	4	7/2/01
General	4	7/2/01
Drilled Shaft Types	4	7/2/01
Design Considerations	5	7/2/01
Construction	6	7/2/01
Settlement Tolerances	9	7/2/01
Safety Factors	9	7/2/01
Spread Footing	10	7/2/01
General	10	7/2/01
Types of Spread Footing	10	7/2/01
Settlement Tolerances	10	7/2/01
Safety Factors	11	7/2/01
Construction	11	7/2/01
Piles	11	7/2/01
General	11	7/2/01
Types of Piles	11	7/2/01
Settlement Tolerances	12	7/2/01
Safety Factors	12	7/2/01
Construction	12	7/2/01
Geotechnical Relationship	13	7/2/01
Determination of Soil Properties	14	7/2/01

Bridge Geotechnical Reports	14	7/2/01
Design Kick-off Meeting & Stage I Design	14	7/2/01
Stage II Design	15	7/2/01
Stage III Design	15	7/2/01
SUBSTRUCTURE	16	7/2/01
Abutment	16	7/2/01
General Consideration	16	7/2/01
Pier	18	7/2/01
General Consideration	18	7/2/01
Pier Protection	18	7/2/01
APPROACHES	18	8/20/01
Approach Slab	18	8/20/01
Anchor Slab	19	8/20/01

SCOPE

The main purpose of this section is to document ADOT Bridge Group design criteria as related to bridge substructure and foundation geotechnical issues.

Bridge substructure is often referred to as the bridge components below the bearings of the superstructure. They consist of abutments, piers and their foundations. The function of the substructure is to support all the live and dead loads and earth and water pressure loading in accordance with the general principles specified in AASHTO Design Specifications. It can be reinforced concrete, steel or the combination of both. The design and detailing aspects for bridge substructure shall refer to Section 3, 4 and 5 of this guideline.

DEFINITIONS

Drilled Shaft	A deep foundation unit, wholly or partly embedded in the ground, constructed by placing fresh concrete in a drilled hole with or without steel reinforcement. Drilled shafts derive their capacity from the surrounding soil and/or from the soil or rock strata below its tip. Drilled shafts are also commonly referred to as caissons, drilled caissons, bored piles, or drilled piers.
Spread footing	A spread shallow foundation that derives its support by transferring load directly to the soil or rock at shallow depth.
Piles	A relatively slender deep foundation unit, wholly or partly embedded in the ground, that is installed by driving, drilling, auguring, jetting, or otherwise and that derives its capacity from the surrounding soil and/or from the soil or rock strata below its tip.
Abutment	A structure that supports the end of a bridge span and provides lateral support for fill material on which the roadway rests immediately adjacent to the bridge.
Pier	That part of a bridge structure between the superstructure and the connection with the foundation.

FOUNDATION

Drilled Shaft

GENERAL

A drilled shaft foundation consists of excavating a round hole by machine, placing a reinforcing cage in the hole and filling the hole with concrete. All drilled shafts shall be constructed vertically. Battered drilled shafts are not allowed. The geotechnical engineer is responsible for recommending the minimum diameter of shaft recommended and providing the necessary information for determining the minimum required embedment below a specified elevation to develop the required axial load. He is also responsible for determining the soil properties in each layer to be used in analyzing lateral loads and whether slurry methods of construction may required. If necessary, methods of testing the shaft after concreting will be specified in the Bridge Geotechnical Report.

DRILLED SHAFT TYPES

Four types of drilled shafts are currently used at ADOT and are listed as:

Prismatic Drilled Shaft	Drilled shaft has constant diameter throughout its entire length.
Rock Socket	Refers to the lower portion or the entire length of the drilled shaft embedded into the rock strata which requires special heavy duty drilling equipment. The rock socket is normally six inches smaller in diameter than the regular drilled shaft portion. The minimum embedment of rock socket shall be ten feet. Separate pay item shall be set up because of added cost of rock drilling.
Bellied Shaft	A drilled shaft with the flared bell shape at the tip so that the drilled shaft bearing area is increased. Generally it has the advantage when stiff foundation material is encountered and results in higher bearing capacity so that the drilled shaft length can be reduced.
Telescoping Shaft	A drilled shaft with one or more segments of consecutively smaller diameters. In order to avoid using excessive steel casing for shoring purpose during drilled shaft construction when very loose foundation material is present, telescoping augering technique can be beneficial to accommodate varying soil conditions.

DESIGN CONSIDERATIONS

The bridge designer is responsible for ensuring that the allowable axial capacity is not exceeded for any AASHTO group Loading and that the shaft can withstand the applied lateral loads.

Unless specified otherwise in the Bridge Geotechnical Report, the following criteria should be used in designing drilled shaft foundations:

- Drilled shafts shall be spaced a minimum of three diameters measured center to center of the shafts.
- The length of a shaft should be limited to 20 times its diameter.
- Shafts, which will remain open in the dry, should have 3 inches minimum clear cover to the outside edge of the shaft.
- Shafts, which may be constructed using slurry, should be designed to have 6 inches minimum clear.
- Vertical reinforcing should be detailed to provide the minimum recommended clearance in AASHTO Article 4.6.6.2.1. In no case shall the clearance between vertical reinforcing be less than 4 1/2 inches.
- Horizontal ties should be spaced at 6 inches minimum.
- The footing shall be sized to extend a minimum of 9 inches from the edge of a shaft.
- A 2-1/2 inch Schedule 80 or a 2 inch Schedule 40 PVC pipe for gamma-gamma logging shall be installed inside the drilled shaft if wet excavation is anticipated for the drilling.
- If collapsing material or intermittent large boulders are found during the geotechnical investigation, a test shaft boring may be performed as part of the investigation and the results included with the final bridge foundation report. Test shaft borings should only be used when there is legitimate uncertainty regarding the suitability of this foundation option. In most cases, the geotechnical engineer and the bridge designer should be able to make the determination based on new and historic site data without the need for the costly test shaft boring.
- Rock sockets may be appropriate where the depth to bedrock is too short for adequate development length of the reinforcing but too deep for economical spread footings.

CONSTRUCTION

Drilled shaft construction specifications shall refer to Section 609, Drilled Shaft Foundation in ADOT Standard Specifications for Road and Bridge Construction, 2000 Edition.

A drilled shaft is a type of deep foundation which transmits loads from a structure to the soil. Deep foundations are required when the upper soil layers are weak, the effects of the mining, degradation and scour must be considered in design and when there are construction constraints which might otherwise require shoring. The method of construction consist of drilling a hole in the ground, placing a reinforcing cage in the hole and pouring concrete into the hole.

Based on how drilled shafts transmit their axial loads to the soil, they can be categorized into three types: Skin Friction, End Bearing and Combination. The type of shaft is important in that it can influence the type and amount of inspection required. For example, an end bearing shaft requires better cleanout of the bottom of a shaft than a friction shaft.

There are five basic methods to construct a drilled shaft: dry wet slurry, temporary casing or permanent casing. The method of construction is important since it can affect the load carrying capacity of a shaft. For example, permanent casing will affect the capacity of the soil to resist loads for skin friction shafts.

The first use of drilled shafts as deep bridge foundations in Arizona occurred in 1980 on the SR87 Bridge over the Salt River. The need to design for the effects of mining and deep scour and the need to have a foundation type which would penetrate through the sand, gravel and cobble layer, led to the use of drilled shafts. Due to ADOT's lack of experience in this type of construction the specifications required the contractor to prove he could construct a shaft through the sand, gravel and cobble layer using slurry by requiring a test shaft. The contractor constructed a shaft and exposed it for our field personnel to inspect. The shaft was unacceptable. After a few more attempts, the contractor was able to construct a successful shaft.

From this early beginning ADOT gradually developed extensive guidelines for in-depth method specifications which attempted to cover all conditions. This practice required close supervision by our inspectors and trained inspection staff. Extensive boring programs and geotechnical reports were developed for each site.

This worked for a while, as most shafts were constructed in the well-known deposits of the Salt River. Over time many conditions changed drastically from ADOT's initial development of our method based specifications. Drilled shafts became the deep foundation of choice being used statewide. This meant that each site had different and varying geological conditions. More drilling contractors entered our market as our usage increased. These drillers possessed varying levels of expertise. The knowledge

developed over the years and needed by our inspectors and resident engineers began to disappear as ADOT lost experienced in-house experts.
To solve these problems, a 12 member committee was assembled to update the specification. The committee consisted of members representing ADOT Bridge, Geotechnical and Construction Administration, contractors and drilling subcontractors. Their initial efforts resulted in attempting to further refine the old method specifications by dictating the material, equipment and procedures that the contractor should use and even going so far as to require prequalification of drillers.

Finally attempts to patch the method based specifications to cover every situation crumbled and a different direction was taken. Using the concepts of Total Quality Management, a new performance based specification was developed based on the Division II Section 5 AASHTO Specifications and the philosophy of partnering.

Major features of the new specification included the elimination of dictating the type and minimum size of equipment to be used, the experience requirements of the drillers and the need to prequalify the drillers. In its place were added the requirements for an installation plan, a method to evaluate the plan and a method to verify the plan with a confirmation shaft.

The specification requires the contractor to submit a detailed installation plan to the Engineer for approval. Major items to be discussed include:

- List of proposed equipment including cranes, drills, augers, buckets, cleaning equipment, pumps casing, and any other equipment to be used. This is a major change from the past where the designers would specify the minimum size of the drilled rigs. This not only allows the contractor the opportunity to choose his own equipment but also puts the responsibility back on the contractor for selecting the proper equipment.

- Details of overall construction operation sequence and the sequence of shaft construction in bents or groups. This is where the contractor will explain his sequence of construction as related to sequence of fills and drilled shafts. Also if the shafts must be constructed in a specific sequence to avoid disturbance to closed-by shafts, the contractor would specify his exact sequence.

- Details of shaft excavation methods, including equipment and procedures for checking the dimensions and alignment of each shaft excavation. This is important so our inspectors and the driller will have a clear understanding of who will take the measurements and how they will be taken.

- When slurry is required, details of the method proposed to mix, circulate, desand and even dispose of the slurry must specified. The slurry method is the most difficult and expensive method to construct a shaft and requires a well-planned effort.

- Details of methods to clean the shaft excavation. This is essential for end bearing and combination shafts where the capacity depends on having a clean bottom to transmit the loads from the shaft to the soil.

- Details of reinforcement placement including support and centralization methods. This involves an element of partnering in that the contractor is provided and an opportunity to modify reinforcing details for better constructibility and receive designer review and approval. The centralizer should be identified and approved up front so there are no surprises in the field.

- Details of concrete placement including the method of pour. The contractor should identify whether the concrete will be placed by freefall, by pumping or by tremie.

- Details of casing dimensions, material and splice details, if required.

- Details of concrete mix designs and mitigation of possible loss of slump during placement. The loss of slump is very important for wet or slurry constructed shafts.

- List of work experience in previous similar projects. This is another major shift from our previous specification. Our old method specification sounded good but was difficult to enforce. Now we have an opportunity to question the experience level of the workers depending on the difficulty of the operation, but ultimately the responsibility of producing the product rests with the contractor.

- Emergency horizontal construction joint method if unforeseen work stoppage occurs. This is very important in any wet or slurry constructed shaft. It is much better to discuss how the problem will be solved before work begins than during a crisis situation. Usually contingency plans including backup pumps and concrete suppliers are sufficient to prevent the problem.

- Other information shown on the plans or requested by the Engineer.

The purpose of the installation plan is to facilitate communication and encourage planning among the involved parties including the contractor. driller, resident engineer, inspectors, geotechnical engineer and the bridge engineer.

The intent is to get the contractor and resident engineer to think ahead about what material, equipment and methods will be used to construct the drilled shafts. The outcome should be a well thought-out plan which demonstrates that the contractor is ready and capable to do the work. The purpose is to ensure that the contractor has prepared for the work, that proper coordination has occurred between the contractor and his subcontractors and the responsibilities have been clearly established. A well thought-out plan will minimize the department's risk of dealing with defective shafts and will help to resolve issues ahead of time.

The second major feature of the new specification is the approval process. The resident engineer is responsible for reviewing and approving the installation plan. The geotechnical and bridge engineers for the project will assist the resident engineer in the review of the plan, with the major effort coming from the geotechnical engineer. The objective of the installation plan is not so much a verification tool for the department as it should be a planning tool for the contractor.

The third major feature of the new specification involves the verification process. The confirmation shaft is an opportunity to test the method and plan in the field under an actual production situation. The confirmation shaft is NOT a test shaft. The purpose of the confirmation shaft is to confirm that the method of construction works. The requirements for a confirmation shaft also provides the geotechnical engineer an opportunity to be on site to identify the soil type, ensuring that the soil is the same as was assumed in design, that the construction method will result in the required capacity, and that the inspectors are properly trained to monitor the work.

Most problems with drilled shaft construction are the result of poor communication and planning. This specification is no magic wand which will eliminate changed conditions or even construction problems. This specification does establish a formal method for the contractor and ADOT to plan their work and to encourage communication and partnering to identify problems and arrive at quick solutions which should result in better construction.

SETTLEMENT TOLERANCES

The settlement of a drilled shaft foundation involving either single-drilled shafts and groups of drilled shafts shall not exceed the movement criteria which are developed to be consistent with the function and type of structure, anticipated service life, and consequences of unacceptable movements on structure performance. The tolerable movement criteria shall be established by either empirical procedures or structural analyses or by consideration of both. Drilled shaft displacement analyses shall be based on the results of in-situ and/or laboratory testing to characterize the load deformation behavior of the foundation materials. Refer to Art. 4.6.5.5.3 and Art. 4.6.5.6.2 for additional guidance regarding tolerable vertical and horizontal movement criteria.

SAFETY FACTORS

Drilled shafts in soil or socketed in rock shall be designed for a minimum factor of safety of 2.0 against bearing capacity failure when the design is based on the results of a load test conducted at the site. Otherwise, shafts shall be designed for a minimum factor of safety 2.5. The minimum recommended factors of safety are on an assumed normal level of field quality control that cannot be assured, higher minimum factors of safety shall be used.

Spread Footing

GENERAL

When good soil materials exist near the surface, shallow foundations in the form of spread footings will normally be the recommended foundation types. For foundation units situated in a stream, spread footings shall only be used when they can be placed on non-erodible rock. Spread footings are normally not placed on embankment material.

When spread footings are the recommended foundation type, the Bridge Geotechnical Report shall contain the allowable bearing pressure, the minimum elevation of the bottom of the footings and the estimated total settlement, differential settlement and the time rate of settlement, if applicable.

The bridge designer shall size the footing to ensure that the allowable bearing pressure is not exceeded for any AASHTO Group Loading and that the footing is properly sized and reinforced to resist the maximum applied moments and shears. The bottom elevations of spread footings shall be set at least to the recommended depth. The minimum top cover over the top footings shall be 1'-6. For footings located at elevations over 5000 feet, the minimum depth of embedment to the bottom of footings shall be 6'-0 to prevent frost heave unless otherwise recommended in the Geotechnical Report. If the possibility for differential settlement is identified, the bridge designer shall ensure that the entire structure is capable of structurally resisting the forces induced by the differential settlement.

TYPES OF SPREAD FOOTING

Two types spread footings are most commonly used:

Isolated Footing	Individual support for the various parts of a substructure unit which may be stepped laterally.
Combined Footing	A footing that supports more than one column for multi-column bents.

SETTLEMENT TOLERANCES

The total settlement includes elastic, consolidation, and secondary components and may be determined by the empirical formula in Art. 4.4.7.2. The tolerable movement criteria (vertical and horizontal) for footings shall be developed consistent with the function and type of structure, anticipated service life, and consequences of unacceptable movements on structure performance. Foundation displacement analyses should be conducted to determine the relationship between estimated settlement and footing bearing pressure to optimize footing size with respect to supported loads by using the results of in-situ and /or laboratory testing to characterize the load-deformation behavior of the foundation soil. The bridge designer shall incorporate the estimated footing settlement value recommended by the geotechnical engineer into the footing design. The tolerable movement criteria for footing foundation settlement shall be as specified in Art. 4.4.7.2.5.

SAFETY FACTORS

Spread footings in solid non-erodable rock shall be designed for Group I loading using a minimum factor of safety of 3.0 against a bearing capacity failure.

CONSTRUCTION

The project geotechnical engineer shall verify each spread footing excavation prior to placement of reinforcement and concrete.

Piles

GENERAL

When good foundation material is not located near the surface, when settlement is a problem, where dimensional constraints exist, or for foundation units located in streams where scour is a problem, deep foundations will usually be recommended. One type of deep foundation is a driven pile. Driven piles may be either steel H piles, steel pipe piles or prestressed concrete piles.

The geotechnical engineer is responsible for recommending when driven piles can be considered, the type of driven pile to be used, the allowable capacity of the pile, the estimated pile tip elevation and any special requirements necessary to drive the piles. When steel piles are used, the corrosive life of the pile will be reported in the Geotechnical Report. The geotechnical engineer is also responsible for running the WEAP87 wave equation computer program to determine the driveability of the specified piles and to develop charts or other guidelines to be used by construction personnel to control the pile driving process.

The bridge designer is responsible for ensuring that the allowable axial capacity is not exceeded for any AASHTO group Loading and that the pile or pile group can withstand the applied lateral loads.

TYPES OF PILES

Batter Pile	Pile driven at an angle inclined to the vertical to provide higher resistance to lateral loads.
Friction Pile	A pile whose support capacity is derived principally from soil resistance mobilized along the side of the embedded pile.
Point Bearing Pile	A pile whose support capacity is derived principally from the resistance of the foundation material on which the piles tip rests.
Combination Point Bearing and Friction Pile	Pile that derived its capacity from contributions of both point bearing developed at the pile tip and resistance mobilized along the embedded shaft.

Two types of piles most commonly used by ADOT are:

Pipe Pile — 14 and 16 inch diameter steel pipes with 1/2 or 5/8 inch wall thickness are generally recommended for the shell. Shell will be driven or vibrated down into the soil until the designed bearing is reached. Steel reinforcing cage will be placed inside the shell prior to concrete placement. It generally serves as a point bearing pile and the shell is not considered as part of the structural element.

Steel H-Pile — ASTM A-36 HP shape will be used. It generally serves as friction pile.

SETTLEMENT TOLERANCES

For purpose of calculating the settlements of pile group, loads shall be assumed to act on an equivalent footing located at two-thirds of the depth of embedment of the piles into the layer that provides support. Elastic analysis, load transfer and /or finite element techniques may be used to estimate the settlement of axially loaded piles and pile groups at the allowable loads. The design of laterally loaded piles shall account for the effects of soil/rock-structure interaction between the pile and the ground. The settlement of the pile or pile group shall not exceed the tolerable movement limits of the structure. Refer to Art. 4.5.6.7 and Art. 4.5.12 for additional guidance regarding tolerable vertical and horizontal movement criteria.

SAFETY FACTORS

The selection of the factor of safety to be applied to the ultimate axial geotechnical capacity shall consider the reliability of the ultimate soil capacity determination and pile installation control. Recommended values for the factor of safety depending upon the degree of construction control specified on the plans are presented in the table of Art. 4.5.6.4.

CONSTRUCTION

Steel Pile — Driving equipment, including the pile driving hammer, hammer cushion, drive head, pile cushion and other appurtenances to be furnished by the Contractor that damages the piling shall not be used and shall be approved in advance by the Engineer before any driving can take place.

Whenever the bearing capacity of piles is specified to be determined by Method B, “Wave Equation Analysis,” the Contractor shall also submit calculations, based on a wave equation analysis, demonstrating that the poles can be driven with reasonable effort to the ordered lengths without damage.

Piles shall be driven to the minimum tip elevations and bearing capacity shown on the plans, specified in the special provisions or approved by the Engineer. Piles that heave more than ¼ inch upward during the driving of adjacent piles shall be redriven.

Test piles and piles for static load tests, when shown on the plans, shall be furnished to the lengths to the lengths ordered and driven at the locations and to the elevations directed by the Engineer before other piles in the area represented by the test are ordered or driven. All test piles shall be driven with impact hammers unless specifically stated otherwise in the special provisions or on the plans.

Pipe Pile — Steel shells for cast-in-place concrete piles shall be of not less than the thickness shown on the plans. The Contractor shall furnish shells of greater thickness if necessary to provide sufficient strength and rigidity to permit driving with the equipment selected for use without damage, and to prevent distortion caused by soil pressures or the driving of adjacent piles. The shells shall also be watertight to exclude water during the placing of concrete.

No concrete shall be placed until all driving within a radius of 15 feet of the pile has been completed, or all driving within the above limits shall be discontinued until the concrete in the last pile cast has set at least 5 days.

Geotechnical Relationship

Since problems requiring geotechnical and structural expertise often result to confusion concerning the responsibilities of each, another purpose of this section is to define the role of the geotechnical engineer and the bridge engineer in design problems involving both fields.

The usual procedure for designing bridge foundation substructure units is as follows:

The bridge designer will develop an Initial Bridge Study and a preliminary location plan.

The geotechnical engineer will conduct a site investigation, identify hole locations according to the Initial Bridge Study and the preliminary location plan, drill and log borings, perform soil testing as appropriate, plot the boring logs and summarize the results in a Preliminary Geotechnical Report. The Report will include preliminary foundation recommendation which identifies the type of foundation recommended for each substructure unit including the allowable loads and required depths so that the bridge engineer can use this information for developing the Preliminary Bridge Selection Report and the Stage III bridge drawings. Additional final borings may be performed if necessary when final design indicates preliminary boring depth is insufficient to determine the additional foundation depth. Test shafts may also will be performed if necessary during this stage in order to provide detail drilling information to the contractor. All the final boring information including the test shaft will be incorporated in the Final Geotechnical Report. The report will consist of the final foundation recommendation so that the bridge engineer will be able to complete the Bridge Selection Report and the Stage III bridge drawings.

The Geotechnical Engineer is responsible for preparing the boring logs for the construction drawings. He/she also prepares the necessary special provisions for construction of the foundation elements. During construction of the bridge foundations, the Geotechnical Engineer oversees geotechnical testing, spread footing excavations and piling and drilled shaft construction. He/she works closely with Bridge Designer to jointly resolve problems during construction or if redesign is needed because of changed site conditions.

The bridge designer is responsible for producing the structural design and construction documents for the substructure units as part of the bridge plans.

Determination of Soil Properties

The element of the subsurface exploration and testing programs shall be the responsibility of the geotechnical engineer who is either the representative from Geotechnical Design Section of Material Group, ADOT or from the contracted consulting engineer for the project, based on the specific requirements of the project and his or her experience with local geologic conditions. According to AASHTO Specifications, subsurface explorations shall be performed for each substructure element to provide the necessary information for the design and construction of foundations. The extent of exploration shall be based on subsurface conditions, structure type, and project requirements. The exploration program shall be extensive enough to reveal the nature and the types and engineering properties of soil strata or rock strata, the potential for liquefaction, and the groundwater conditions. The requirements for minimum exploration depth, coverage, laboratory testing and hydraulic studies for scour shall also be in conformance with the AASHTO Specifications.

Bridge Geotechnical Reports (Preliminary and Final)

DESIGN KICK-OFF MEETING & STAGE I DESIGN

- Request permit for geotechnical investigation
- Minimal Field Investigation (minimum two borings at each bridge, and Laboratory Testing
- Literature research for history, surface conditions, site geology, subsurface conditions, previous similar structures and foundation investigations for existing structure(s)
- Obtain Initial Bridge Study from Bridge Group. If Initial Bridge Report is not available then obtain a preliminary bridge location plan, foundation layout sheet, estimated axial loads, and preliminary design scour depth from bridge engineer.

STAGE II DESIGN

Beginning of Stage II:
Complete Preliminary Bridge Geotechnical Report for each bridge site which includes:

- Site investigation (regional/site geology, test borings and laboratory testing).
- Generalized soil/rock profiles giving initial surface elevations.
- Soil properties.
- Type of foundation options: Spread Footings, Driven Piles or Drilled Shafts (advantage or disadvantage).
- Request test shaft if needed, test shaft request should come after type and size of shaft and location is firmed up by the bridge engineer with consultation with the project geotechnical engineer. They should determine jointly.
- Analysis of the effects of scour, aggradation and/or degradation.

End of Stage II:
Complete Final Bridge Geotechnical Report for each bridge site which includes:

- Review and summarize currently available foundation data and determine whether additional borings are needed.
- Complete test shaft if necessary and document results with report.
- Recommended final foundation alternate including type, depth, allowable loads or bearing pressures, anticipated settlements, and the effects of scour.

STAGE III DESIGN

Prepare and complete Bridge Geotechnical Report for each bridge site with PE seal which includes:

- Introduction
- History
- Proposed Construction with copy of bridge general plan and foundation drawings
- Surface Conditions
- Site Geology

- Subsurface Conditions (prepare foundation data sheet)
- Channel and Hydraulics
- Foundation Recommendation
- Special Provisions
- Cost Estimate
- Discussion

SUBSTRUCTURE

A substructure is any structural, load –supporting component generally referred to by the terms abutment, pier, retaining wall, foundation or other similar terminology. Retaining wall will be discussed in Chapter 11.

Abutment

GENERAL CONSIDERATION

- Types of Abutment
  They can be support by different foundation types, such as spread footing, piles and drilled shafts.
  - Stub Abutment
  - Partial-Depth Abutment
  - Full-Depth Abutments
  - Integral Abutment
- Loading
  Abutments shall be designed to withstand dead load, erection loads, live loads on the roadway, wind loads on the superstructure, forces due to stream currents, floating ice and drift, temperature and shrinkage effects, lateral earth and water pressures, scour and collision and earthquake loadings.
- Loading Effect

Integral abutments shall be designed to resist and/or absorb creep, shrinkage, and thermal deformations of the superstructure.

For computing load effect in abutments, the weight of filling material directly over an inclined or stepped rear face, or over the base of a reinforced concrete spread footing may considered part of the effective weight of the abutment. Where spread footings are used, the rear projection shall be designed as a cantilever supported at the abutment stem and loaded with the full weight of the superimposed material, unless a more exact method is used.

The design of abutment wall should be similar to retaining wall for overturning, overall stability and sliding.

- Settlement

  The anticipated settlement of abutments should be estimated by appropriate analysis, and the effects of differential settlement shall be accounted for in the design of the superstructure.

- Expansion and Contraction Joints

  Consideration shall be given to measures that will accommodate the contraction and expansion of concrete wall.

- Drainage and Backfilling

  The filling material behind abutments shall be free draining, nonexpansive soil, and shall be drained by weep holes with French drains placed at suitable intervals and elevations. Silts and clays shall not be used for backfill. Backfill material shall be compacted to at least 95 percent of the maximum density as determined in accordance with the requirements of the applicable test methods of the ADOT Materials Testing Manual, as directed and approved by Engineer.

- Wingwalls and Cantilever Walls

  Wingwalls may be designed as monolithic with the abutments or as free standing, with an expansion joint separating them from abutment walls. The wingwall lengths shall be computed using the required roadway slopes. Wingwalls shall be of sufficient length to retain the roadway embankment and to furnish protection against erosion. If the wingwall is cantilever off the abutment wall, the cantilever action from the lateral earth pressure shall be taken horizontally from the point of attachment at the abutment.

Pier

GENERAL CONSIDERATION

- Types of Pier
  Piers shall be designed to transmit the loads on the superstructure and the loads on the pier itself to the foundation. The loads and load combinations shall be as specified in Chapter 3. The structural design of piers shall be in accordance with the provisions of Chapter 5, 6, 7, and 8, as appropriate.

  - Solid Wall Piers

  - Double Wall Piers

  - Bent Piers

  - Single-Column Piers

PIER PROTECTION

- Where the possibility of collision exists from highway or river traffic, an appropriate risk analysis should be made to determine the degree of impact resistance to be provided and/or the appropriate protection system.

- Collision walls extending six feet above top of rail are required between columns for railroad overpasses, and similar walls extending 2.35 feet above ground should be considered for grade separation structures unless other protection is provided.

- The scour potential must be determined and the design must be developed to minimize failure from this condition. Where appropriate, round column with adequate spacing (three times of diameter of drilled shaft) shall be considered to be hydraulically efficient and to be able to minimize the scour impact at the pier.

APPROACHES

Approach Slab

Bridge Group Structure Detail drawing SD 2.01 has been developed for approach slabs on all new bridges. The approach slab has been designed using the load factor design method according to the AASHTO Standard Specifications for Highway Bridges. The slabs have been designed to support an HS-20-44 live load, 25 psf future wearing surface and its own self weight. A design span equal to 13 feet has been used assuming settlement may occur and the slab is only supported at the abutment seat and near the far end.

Approach slabs serve three major purposes:

1) They provide a smooth transition structure from the bridge to the approach roadway should the roadway embankment settle.

2) They eliminate the live load surcharge on the abutment backwall when the conditions specified in AASHTO 3.20.4 are satisfied.

3) They provide a structural foundation for bridge barriers or transitions.

Three approach slab options are provided.

<u>Plan A</u> is to be used for right angle bridges.

<u>Plan B</u> is to be used for bridges with skews less than or equal to 45 degrees. This option is not appropriate when used in conjunction with anchor slabs.

<u>Plan C</u> is to be used for bridges with skews greater than 45 degrees and less than or equal to 60 degrees; and for all skewed bridges where anchor slabs are also used.

The bridge drawings shall specify the length of the approach slab and which of the three plans is to be used. The SD drawings show the minimum length of the slabs as 15 feet. This length is adequate for most applications. Where the length needs to be increased to eliminate the need to design a surcharge for an abutment or when ground conditions indicate potential for possible large settlements or when bridge barrier transitions require a greater length, the length of the slab should be increased and the adequacy of the design verified. The bridge designer should consult with the project geotechnical engineer regarding all non-standard approach roadway applications. Inattention to detail in this area could result in serious damage and costly repairs.

The transverse reinforcing in the approach slab was increased to allow a barrier or transition to be supported on the slab. No additional reinforcing is required for this application.

Approach slabs are bid by the square foot; the price including all excavation, concrete, reinforcing steel, guard angles and joint material included in the approach slab and sleeper slab.

Anchor Slab

Bridge Group Structure Detail drawings SD 2.02 and SD 2.03 have been developed for use when anchor slabs are required. When approach roadways are paved with portland cement concrete pavement (PCCP) adequate means shall be provided to prevent pavement growth from causing damage to the bridge. Use of a properly designed anchor slab as shown in SD 2.02 and SD 2.03 is one means of providing such protection. Use of continuously reinforced concrete pavement is another means. For short lengths of pavement less than 200 feet, the Concrete Pavement Alternate detail with a sleeper slab and joint materials shown in SD 2.01 may be used.

Pavement growth is caused by cyclic temperature changes which cause the pavement joints to open during cold temperatures and close during hot temperatures. If the joints are not properly sealed and well-maintained, they will fill up with incompressible material during cold cycles and close during hot cycles. This cyclic process of the pavement joints opening, filling up with material and closing, builds up huge compressive forces in the pavement. As the forces increase, the free ends of the pavement will move. A bridge abutment expansion joint will act as a free end of the pavement, forcing the expansion joint to close and damaging the abutment backwall. The anchor slabs are designed to resist this movement by mobilizing the passive soil pressure through the lugs.

Anchor slabs serve a dual purpose of providing protection to the pavement and to the abutment backwall due to pavement growth. In addition they can provide a structural foundation for bridge barriers or transitions.

Two anchor slab options are provided.

> Type 1 (SD 2.02) is used when the length of the approach pavement exceeds 700 feet.
>
> Type 2 (SD 2.03) is used when the length of the approach pavement is between 200 and 700 feet.

The bridge drawings should specify which of the two SD drawings is to be used. The anchor slabs are designed to be used together with an approach slab and sleeper slab. The approach slab must be squared off to be compatible with the anchor slab details.

Selection of the appropriate approach and anchor slabs should be performed with close consultation with the project geotechnical engineer and concrete pavement designer. Documentation of the selection should be recorded in the Bridge Selection and Bridge Geotechnical Reports.

The transverse reinforcing in the anchor slab is adequate to act as a structural support for a barrier or transition. No additional reinforcing is required for this application.

Anchor slabs are bid by the square foot; the price including all excavation, concrete, reinforcing steel, and load transfer dowels included in the anchor slab.